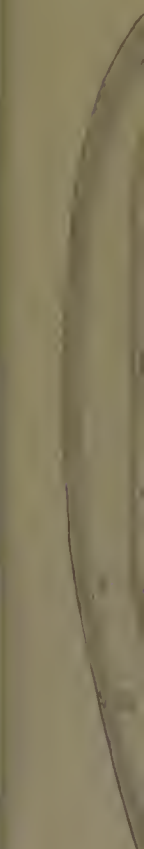


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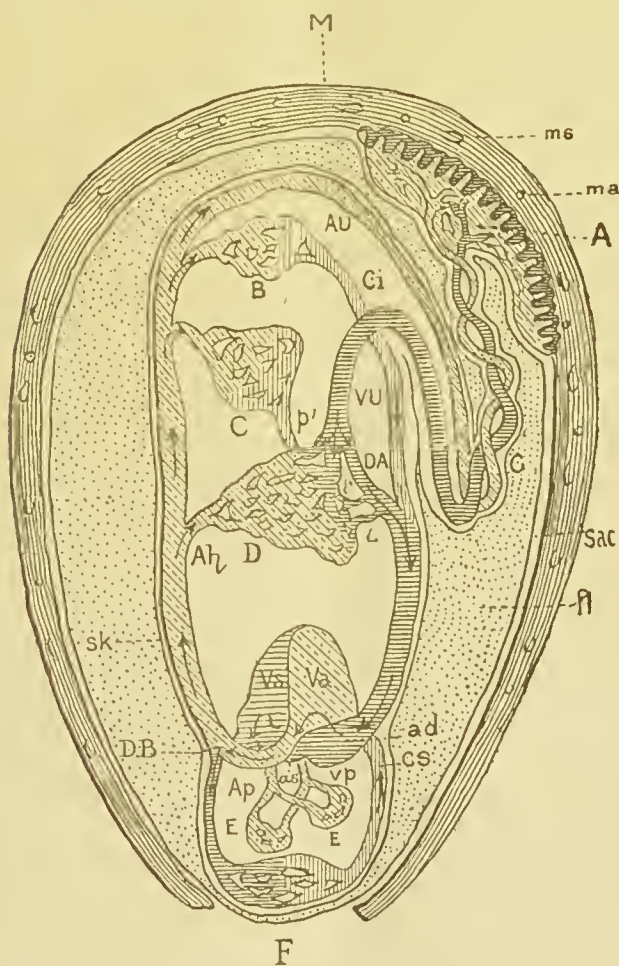
ASPHYX



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THE NATURE AND TREATMENT OF ASPHYXIA NEONATORUM



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TO
ALEXANDER REID, ESQ., M.A., M.D.,
AND MY OTHER FRIENDS IN NORTH LONDON,
I CORDIALLY INSCRIBE THIS PAMPHLET
IN THE
CHERISHED RECOLLECTION OF MANY YEARS
OF PROFESSIONAL AND SOCIAL
GOODFELLOWSHIP.

PREFACE.

BELIEVING that a consideration of the conditions and disorders of the foetal circulation has an important bearing upon the right understanding of the nature and treatment of diseases of the adult heart, the writer does not regard the following pages so much as a contribution to obstetric medicine as the introduction to a study of disorders of the circulation.

A. M.

LONDON, *October 8, 1894.*

THE NATURE AND TREATMENT OF ASPHYXIA NEONATORUM.

I. LITERATURE AND STATISTICS.

ASPHYXIA NEONATORUM is usually classed with diseases of the respiratory organs. While admitting its essential cause to be interference with placental respiration, there seems to me to be greater reason in grouping this disorder with diseases of the circulation. The interrupted oxygenation is not due to deprivation or deterioration of *air*, as in cases of suffocation from other causes, but to vitiation of the circulating fluid. It is, therefore, no more a lung disease than are disorders of what is metaphorically termed "interstitial respiration," while its mechanical pathology is chiefly cardiovascular.

In the *Practitioner* for February and March, 1888, I published an article on the Nature and Treatment of Cyanosis, in which I endeavoured to show that the key to a solution of the mechanism of that condition lay mainly in the state of the ductus arteriosus as regards closure, and argued that, "as the repletion of the pulmonary circulation post partum is normally the main cause of the closure of the ductus arteriosus, it follows that a patency of the latter in most cases argues an imperfect circulation of blood through the lungs, with deficient thoracic aspiration of the circulation, unless the volume of blood has other means of reaching the aorta and the lungs than by way of the pulmonary arteries. Thus the degree of closure in this passage may be taken as an index to the amount of normal lung function, and also to the degree of diversion of the normal blood current." In November of the same year Fritz Schantz¹ published a paper on the mechanical closure of the ductus arteriosus, in which his observations and argument led him to regard the ductus arteriosus as the most important factor in many cases of asphyxia neonatorum. So strongly is he of this opinion

¹ Pflüger's Archiv für die Gesamte Physiologie, November, 1888.

that he expresses his belief that the recovery from asphyxia in newly-born children by Schultze's method is dependant less upon ventilation of the lungs than upon a closure of the ductus arteriosus by the forcible descent of the diaphragm which takes place during that manipulation—a closure, according to him, causing a diversion of the circulation lungwards, and thus the establishment of aerial respiration. The conditions of cyanosis from cardiac malformation and those of asphyxia neonatorum are not, of course, identical, but, inasmuch as the former is due to the persistence of foetal channels, they are closely allied; and there is accordingly much in Schantz's argument which is in agreement with the conclusions arrived at by myself in the paper to which I have referred. Cyanosis is admittedly a disease of the circulation, and asphyxia neonatorum, as I have stated, must in its mechanical effects be regarded in the same light.

The literature of the subject is extensive, but the condition has, as a rule, been treated more exhaustively by continental, and especially German, than by English writers, although it is to William Harvey that the almost perfect elucidation of the foetal circulation is due, as well as the perfect explanation of the course of the blood in the adult; for, although he believed that blood passed from the vena cava through the foramen ovale into the pulmonary veins and thence into the left auricle, his conception of the foetal circulation was, with this exception, practically correct.³ References to other authorities will be found in their own place in the following pages.

The condition in question is as important as it is interesting and probably causes the premature extinction of a greater amount of male than of female life. It can, however, only be said that this is probably the case as to males, because only an indirect inference can be made from the Registrar-General's reports, a brief study of which will be a useful introduction to a further consideration of the subject. It is, perhaps, excusable that a register which is concerned with births and deaths should assume life to commence after, not before, birth, and death to be only possible after the commencement of aerial life. There is in consequence no registration of "stillbirths,"

² Loc. cit., p. 261.

³ *Exercitatio Anatomica de Motu Cordis et Sanguinis*, cap. vi., p. 39. Ed. 1766.

although an informal certificate is necessary before the still-born infant can be buried. There would no doubt be difficulties in doing otherwise were the probable causes of all stillbirths to be demanded in a certificate, difficulties social as well as professional. The patient might reasonably object to the publication of her specific taint, if such existed, while the accoucheur might hesitate to acknowledge what may have been want of dexterity on his part or slow perception of the progress of intra-uterine asphyxia. There does not, however, seem to be any sufficient reason why the fact of the stillbirth of viable children recently asphyxiated should not find a place in the registrar's reports and contribute to the completeness of those very valuable returns. The large and heterogeneous column of "premature births" registered as causing death up to twelve months might usefully and logically be preceded by one noting the stillbirth of children born after the average period of viability. The chief causes of death in infants born alive are very properly set forth as accurately, no doubt, as is possible under the circumstances. It cannot, however, be doubted that a very large proportion of stillbirths is due to that very "atelectasis" which figures so prominently in the returns as a cause of death in children "born alive," and the prevention of which—possible in many cases, although doubtless also unavoidable in many others—would be promoted by the required certification of the proximate cause of intra-uterine death in such cases. The stethoscope is as useful in labour as the forceps. It frequently tells the physician when he must use the means which his art places at his disposal to save life. Even in the interests of the mother, one of the most delicate tests of her condition and progress in labour is the state of the foetal circulation; while, in the interest of the unborn but viable child, it is, of course, of the first importance. Yet it would be difficult to say how many cases even of lingering labour are attended throughout the country without a single application of the stethoscope to ascertain the condition of the foetal vitality. The vast majority of atelectatic and moribund children might, I am persuaded, enter upon extra-uterine life with every prospect of healthy survival were the condition of their hearts' action accurately noted and interpreted during labour. Of deaths from atelectasis, I find from the record in the returns for England, with an estimated population of 29,199,066, that there were during the year 1891

547 of males and 544 of females ; in those for Scotland during 1890, and with a population of 3,735,573, 68 of males and 41 of females ; and in those for Ireland, with a population of 4,681,248 during 1891, 11 of males and 4 of females. Or, taking the totals, there were for England 1091 deaths from atelectasis, for Scotland 109, and for Ireland 15. Scotland, in other words, with a population less than a seventh that of England, has a death-rate from this cause about a tenth of that in England, while Ireland, with a population nearly a million greater than that of Scotland, and therefore about a sixth of that of England, shows an atelectatic death-rate a seventh less than that of Scotland and about a seventieth that of England. There is thus a very remarkable disparity, in this respect, in favour of Ireland, and it is easy to attribute it to imperfect registration ; but if this is operative there are probably also other causes at work, into which it may be instructive to inquire. It is interesting, in doing so, to compare the birth-rate of the three kingdoms and also the proportion of deaths in childbed. The average birth-rate of England per 1000 persons living was in 1891 31·4 ; that of Scotland in 1890, 30·4 ; while that of Ireland in 1891 was 23·1. The birth-rate of Ireland, therefore, like the atelectasis-rate, was considerably less than that of the sister kingdoms ; but the disparity of the former is much less than that of the latter, and cannot, therefore, *of itself* account for the very small percentage of deaths registered from this cause, while the birth-rate of Scotland, it will be observed, is nearly equal to that of England, but the death-rate from atelectasis is out of proportion less in view even of this fact.

The number of deaths amongst mothers in childbed in England during 1891 and from all causes was 4787, to which "puerperal fever" contributed 1973, and various other "accidents" of parturition 2814. Thus a death-rate of 5·24 was composed, and was higher than that of any year since 1875. In Scotland during 1890 363 deaths were registered under "diseases of parturition," and 324 from puerperal fever, making a total of 687 deaths in childbed. This yields a proportion of 5·5 deaths to 1000 children born. In Ireland the deaths from "puerperal fever" numbered 236 in 1891, being 89 below the average for the ten preceding years and 16 under the number for 1890 ; while "accidents" from other causes amounted to 421, or a total of 657. We thus obtain a maternal death-rate of 6·7 to 1000 children born,

and that notwithstanding an acknowledged diminution in the mortality from puerperal fever.

It will be observed, further, that the deaths from atelectasis in all portions of the country were greater among male than female children. It is interesting in this connexion to note a fact mentioned by the Registrar-General for England in the report for 1891 (p. 9)—namely, that in the Celtic areas of England and Wales the proportion of male to female births is greater than in the non-Celtic areas, and also that this male preponderance is shown in the "sex-rate" of Scotland and Ireland, the more Celtic portions of the United Kingdom. He suggests race as an explanation. This fact may, perhaps, account in a measure for the high rate of maternal death in Ireland, which is probably the most Celtic portion of the country; but when one notes the lower maternal death-rate in Scotland, where the Celtic element must be accorded a considerable influence, it would appear that there must be some additional factor at work. When the very low "atelectasis" death-rate of Ireland is taken into account, as well as the value attached to infant life in Roman Catholic communities, we begin to gain some light both upon the causes of the proportionately greater maternal death-rate in that country and the small ratio of death from atelectasis registered there. The greater proportion of male births would argue, on the whole, greater difficulty in labour, and that this should be coupled with the production of a larger number of children free from atelectasis can only mean that the vitality of the fœtus is more carefully watched in Ireland than in those portions of the kingdom where the safety of the mother is the guiding consideration. I do not wish to suggest that the mother is *neglected* in Ireland, or that the condition of the child is overlooked in England and Scotland, but it would naturally follow that the balance of life would be in favour of that organism which has most consideration paid it, and it requires a more than average degree of skill to pay equal attention to both.⁴ These

⁴ The returns for Scotland for 1891 and for Ireland for 1892 were not published when the figures from which the above table was compiled were accessible. On examining the more recent returns for Scotland and Ireland, however, I find my argument enforced. The birth-rate of Scotland in 1891 per 1000 persons living was 31·2; the total maternal mortality was 718, of which 378 were due to puerperal fever and 340 to other accidents of childbirth, while the maternal death-rate per 1000 births was 5·6; the male deaths from atelectasis numbered 70 and the female 60, making a total of 130. In Ireland the birth-rate during

considerations have thus a bearing upon the subject of this paper—namely, the causes and *nature*, and the timely prevention and prompt and enlightened *treatment*, of asphyxia neonatorum, or apparent death in the newly born.

II. PHYSIOLOGY.

It is the function of the placenta to convey nutriment and oxygen to the fœtus and in a measure to act as an emunctory to it; but, as Schroeder⁵ remarks, inasmuch as the fœtus can exist for a longer time without nourishment than without oxygen, the due conveyance of the latter is most important in considering the question of apparent death in the newly-born. Anatomists have demonstrated the complete separation of the maternal and foetal vessels and by injections have proved the continuity of the umbilical arteries and veins, on the one hand, and of the maternal venous and arterial systems, on the other. Having regard to the varying conditions of pressure to which these sources of foetal life are subjected, it is not without interest to note the spongy and compressible character of the placenta and the great variety it exhibits in lobulation, in the depth of its sulci, and in thickness and general consistency in different cases. The anatomical peculiarities of the vascular connexion between mother and child in the umbilical cord are also of interest. In a cord of average length the most notable feature is the spiral arrangement of the bloodvessels, and a less evident, but nevertheless important, circumstance is the fact that the umbilical arteries *widen* as they approach the placenta—a condition which, as Galabin⁶ remarks, diminishes the force of the circulation towards the placental end of those vessels, but one also which, I shall argue, has an influence in producing the cardiac retardation noted in the fœtus when the uterus contracts. In association with this, the spiral course taken by the umbilical vessels generally

1892 per 1000 persons living was 22·5; the total maternal mortality was 678, of which 275 were due to puerperal fever and 403 to other accidents of childbirth, whence a maternal mortality per 1000 children born of 6·4. Male deaths ascribed to atelectasis numbered 13 and female 4, making a total of 17. These figures also show the small birth-rate, high maternal mortality, and small death-rate from atelectasis in Ireland as compared with other portions of the United Kingdom.

⁵ *Lehrbuch der Geburtshilfe*, p. 587.

⁶ *Midwifery*, first edition, p. 69.

must be regarded as erecting a barrier against excessive afflux and reflux of blood either towards the placenta or foetus. The principle on which spiral vessels generally and retia mirabilia act I endeavoured to explain from a study of the circulation in the sheep on a former occasion.⁷

It is only necessary in this place to mention cursorily the preponderant influence of the right ventricle in the foetus, the easy transmission of blood into the aortic system through the ductus arteriosus, and the relief of dextral cardiac pressure from the presence of the inter-auricular foramen ovale. It is of less, but nevertheless of some, importance to remember also that the greater portion of the most highly oxygenated blood in the foetus circulates in its cephalic extremity, which includes the respiratory and cardiac centres; that the channel for this oxygenation is the umbilical vein; and that the foetal arterial system finds exit and relief through the umbilical continuations of the hypogastric arteries.

The act of respiration at birth develops the latent pulmonary circulation, depletes the foetal channels in the heart and great vessels, and promotes their closure. Attempts at respiration in utero have a similar tendency, as will be shown presently, but attempts are at best but partial successes and, under the circumstances in question, are doomed to failure. The foetal attempts to establish an extra-uterine vascular system give way, even after the death of the young organism, to the normal conditions characteristic of foetal apnoea. Schantz has ingeniously argued⁸ that, the aortic end of the ductus arteriosus being fixed by that vessel, while the end issuing from the pulmonary artery is movable, the duct is capable of being influenced by the change of position of the pulmonary artery and diaphragm which ensues upon the establishment of aerial respiration. The former, he thinks, pulls upon it, rotating forwards with the inflating lungs, while the latter in its descent, together with the forward-moving sternum, drags upon the pericardium and through this investment upon the ductus arteriosus. That such a mechanical traction cannot be without influence in producing that closure of the duct characteristic of the fully developed circulation is very probable; I do not, however, think that it disproves the correctness of the opinion which would regard the simple diversion of the blood stream lung-

⁷ Dextral Valvular Disease, p. 30.

⁸ Loc. cit.

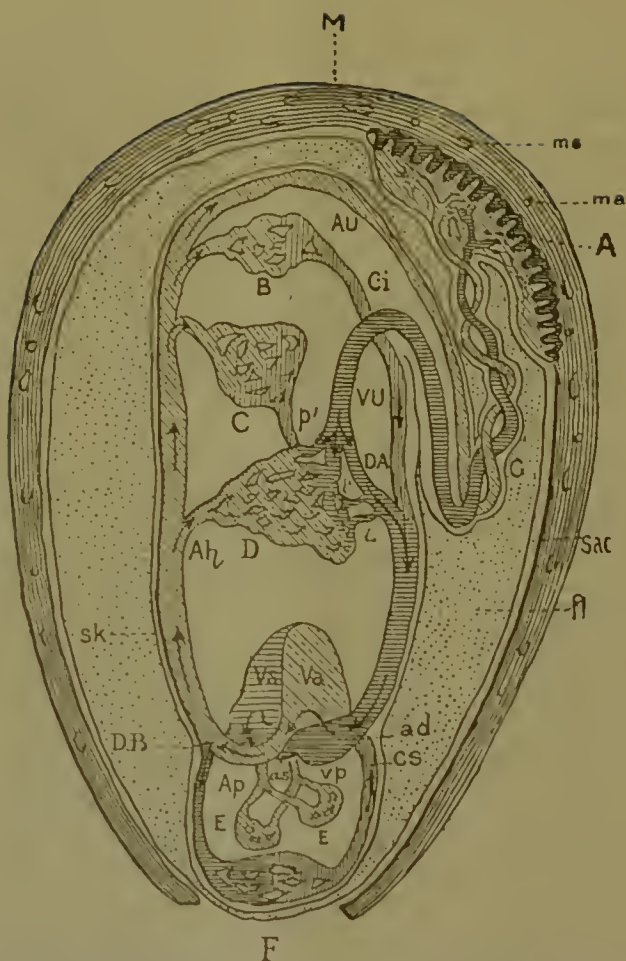


Diagram of the materno-fœtal circulation, modified from the plate in Spiegelberg's Text-book of Midwifery, Sydenham Society's Translation, vol. i., p. 134. M, Vertical section of the uterus. ms, Maternal sinuses. ma, Maternal arteries. A, Placenta. B, Circulation through the lower part of the body. C, Intestines. D, Liver. EE, Lungs. F, Circulation through the upper part of the body. DA, Ductus venosus Aranzl. vu, Umbilical vein. l, Superior hepatic vein. l', Inferior hepatic vein. p, Vena portæ. ci, Cava inferior. cs, Cava superior. ad, Right auricle. as, Left auricle. vd, Right ventricle. vs, Left ventricle. ap, Pulmonary artery. vp, Pulmonary vein. Ah, Hepatic artery. Au, Umbilical artery. DB, Ductus Botalli. sac, Amniotic sac. fl, Amniotic fluid. sk, Fœtal skin. Spiegelberg's diagram was drawn by Strasse from the description of Hasse. In my modified diagram dark horizontal shading indicates the blood, chiefly arterial; vertical shading, that chiefly venous; oblique and interrupted shading, the blood about equally mixed. The dotted space is the amniotic fluid, and the uterine muscle is indicated by M.

wards as the first and main factor in this closure. It is the establishment, I believe, of the collateral circulation, which gradually closes the previously used channel, not the sudden closure of the latter, which at once establishes the collateral circulation. As is well known, and as Ballance and Edmunds remark in their treatise on Ligation in Continuity (p. 75), in which also they quote at length Schantz's views, "it must be remembered that for many days after birth the duct is found pervious to a stream of water, and during life, though closed in the centre, yet at either end the walls are separated by blood which must be under the same pressure as that within the pulmonary artery and aorta." The degree of traction and rotation, moreover, must intermit with the respiratory movements, while the left intra-ventricular pressure, although not so much exceeding the right during the first week of life as it does later, must be greatly raised from the influx of pulmonary blood and ligation of the umbilical cord. It is probably even at this period somewhat higher than right cardiac pressure, and pressure in the aorta and pulmonary artery must be related to that in their respective ventricles. Under these circumstances there is probably more or less oscillation of blood in the still pervious duct, which is incompatible with permanent closure by the means which Schantz suggests. As Harvey⁹ remarks, "that arterial canal has no valve to prevent the movement of the blood hither and thither," and this must be more or less the case so long as the passage is pervious. The very presence of an occasional clot in the vessel, to which Ballance and Edmunds refer,¹⁰ is rather evidence of a slowing circulation than of a perfectly interrupted one in most instances; for if the clot indicates a condition strictly analogous to ligation it ought to occur frequently, not exceptionally. Finally, the experiments of Erichsen, to which I shall have occasion to refer later, are against an absolute acceptance of Schantz's views. It may, however, be reasonably concluded that any circumstance which tends to prevent the establishment of the pulmonary circulation tends to maintain the patency of the ductus arteriosus, and, *vice versâ*, that any temporary or partial restriction of this patency will tend likewise to engorge, if not develop, the pulmonary circulation and also produce

⁹ Op. cit., cap. vi.

¹⁰ Op. cit.

that superficial venous congestion which has been termed "cyanosis," and which probably plays a part and indicates a stage in most cases of asphyxia neonatorum.

Leaving out of consideration the causes of death in the early ovum, intra-uterine death in the viable fœtus may be due to premature detachment of the placenta, with accidental hæmorrhage; changes in the texture of that organ due to extravasation of blood or inflammation, in some cases associated with constitutional disease such as diabetes; imperfect oxygenation from "anæmia"; or to placental hyperplasia usually if not always caused by the syphilitic virus, which, without detachment of the placenta, causes such a strangulation of the materno-fœtal circulation as to induce the death of the child. Priestley, quoting Fraenkel, and drawing upon his own experience, refers to this cause of abortion or stillbirth in his Lumleian lectures on the Pathology of Intra-uterine Death.¹¹ I have myself met with a very instructive example of this condition in which the production of viable children at term was associated with diminution in the size of the placenta after specific treatment and wearing out of the disease by lapse of time. In this case the poison was conveyed by the husband, who married before all evidence of secondary syphilis had disappeared.¹² Apart, however, from the general question of intra-uterine death, to which it is only necessary at present to refer, and in order to appreciate the causes of apparent death in the newly born, it is necessary to consider the incidents and accidents of parturition. These may be divided into two groups—those, namely, which affect the fœtal circulation directly and those which influence it indirectly. To the former belongs any interference with the materno-fœtal circulation by undue pressure upon, or interruption of, the placento-funicular circulation by accidental compression, stretching, or entanglement of the cord during labour or delivery, and by the excessive and general squeezing of the uterine contents, including the placenta, by prolonged or tetanic contractions of the uterus, natural or induced—that is, resulting from the use of an oxytocic. In the second group must be placed cases of apparent death caused by too prolonged or powerful a compression of the fœtal head during natural and violent efforts

¹¹ THE LANCET, April 30th, 1887

¹² Abstract of Transactions of the Æsculapian Society, 1884, p. 48.

at extrusion of the child, or too powerful compression and traction by forceps or other methods of delivery. The causes of apparent death, pushed a little further, are of course those of actual death. The mechanism whereby these agencies produce their results will be apparent when discussing the pathology of foetal death.

III. SIGNS.

The proof of death in these cases is cessation of the action of the heart—the *ultimum moriens*. The evidence of threatened death is disorder in the action of that organ. The dying adult heart usually quickens; it may even assume the “tic-tac rhythm” of foetal life. The dying foetal heart, on the other hand, becomes progressively slower, until it ceases to beat. Acceleration, therefore, in the latter does not generally portend immediate danger, while the converse, except during normal uterine contraction, does. It is agreed that the foetal heart first becomes distinctly audible in the fifth month of pregnancy and becomes somewhat slower and still more distinctly audible as pregnancy advances. Both cardiac sounds may be heard, and, although their duration does not differ so much as in extra-uterine life, the diastole, even in the foetus, is usually marked by greater prolongation and accentuation than the systole. Diminution in the foetal heart-rate is due either to raised arterial pressure or to exhausted or blunted sensibility of the cardiac centre in the medulla, and probably also in some cases to direct inhibition of the pneumogastric nerve from intra-cephalic pressure. It can scarcely be that the usual retardation of the foetal heart during normal uterine contraction is the result of pneumogastric inhibition from imperfect oxygenation of the blood; it is more probably due to raised arterial pressure in the umbilical arteries, a retardation which is favoured by that increase in the diameter of these vessels as they approach the placenta of which mention has already been made, while it is also moderated by their spiral arrangement. Schultze rejects the influence of this retardation in the foetal circulation and, recognising the difficulty involved in reconciling the forbearance from attempts at respiration on the part of the foetus with a theory of vagus irritation from accumulating carbonic acid in the

blood, enters upon a not very convincing argument in support of his theory by assuming a simultaneous diminution in the irritability of the respiratory centre.¹³ The maternal pulse, as is known, is quickened during uterine contraction in spite of a raised peripheral pressure; but the mother is not only sentient but also emotional. Her accelerant nerves by cerebral impulse control the pneumogastric reflex, which, not so controlled, would produce retardation of the heart's action. The fœtus is sentient, but not emotional, and reacts as though it were all spinal cord; the pneumogastric reflex, therefore, under these circumstances, exhibits its normal reaction up to a certain point. When, however, such retarded action of the fœtal heart fails to resume its habitual acceleration during the pauses in uterine contraction it may be assumed that, in addition to this mechanical and vascular causation, there is irritative or exhausted central action from accumulation in the blood of carbonic acid. Such retardation is significant of danger to the life of the fœtus. Schwartz¹⁴ has carefully studied this question and states that retardation of the fœtal heart takes place in 35 per cent. of cases during the first stage of labour; in 46 per cent. in the expulsive period; while in 19 per cent. it is absent, or only noticed when the head is passing through the vulvar opening, although these figures are not exclusively applicable to vertex presentations. "In a third of the cases," he further remarks, "the slowing tends to prolong itself into the interval between the pains. In these cases the child, if not seriously injured, comes into the world with more or less well-marked evidence of inspiration." These changes may be detected by auscultation with the stethoscope and are only liable to one fallacy—namely, the temporary loss or lessened audibility of the fœtal heart from change of position on the part of the fœtus; if, however, lessened audibility be associated with normal acceleration, this sign may be regarded as due to distance of the heart from the surface of the abdomen rather than to diminished vitality of the fœtus.

On internal examination, when the fingers can feel the umbilical cord, the fœtal pulse rate may, of course, be counted like the pulsations of the adult arteries, and its rate

¹³ Gerhardt's *Handbuch der Kinderkrankheiten*, vol. ii., p. 11, Art. Asphyxie.

¹⁴ *Archiv für Gynäkologie*, vol. i., 1870, p. 361 et seq.

and regularity have the same significance as the sounds revealed by the stethoscope. When, in addition, during obstetric manipulations attempts either at abdominal or thoracic respiration are perceptible to the hand, danger to foetal life is imminent. Such respiratory movements may be attempted in utero, not only in cases of podalic version, when they may be seen by the accoucheur, but also in other cases, when they may be felt by the introduced hand.¹⁵ Schroeder¹⁶ quotes Schultze as having heard a snuffling ("schlürfendes") murmur with the stethoscope at the same moment that he could determine by the introduced hand thoracic breathing on the part of the foetus. Such a respiratory murmur, in order to be diagnostic, would have to be confirmed by intra-uterine palpation, as in the above instance, and is only of accidental interest.

Finally, in the presence of a sufficient quantity of air in the cavity of the uterus the occurrence of intra-uterine foetal respiration may be denoted by a foetal "cry"—*vagitus uterinus*.¹⁷ I have also on more than one occasion believed that I have heard the foetal cry before the delivery of the head in the case of multiparæ in whom the infra-uterine section of the birth-way has been freely dilated—a *vagitus vaginalis*.

IV. PATHOLOGY.

The first case of a condition new to us is frequently that which impresses itself most vividly upon our memory. When a senior student of medicine at the University of Edinburgh I attended a primipara during labour. The vertex presented, the labour was protracted, and the membranes remained unruptured until about an hour before the birth of the child. The latter was stillborn, without instrumental aid, and probably in consequence of such aid not having been rendered. The foetal heart had been well heard during labour. I examined the body eight hours after death, the late Dr. Angus Macdonald being present. There was a large quantity of serous fluid in the pleural and pericardial cavities and much uncoagulated blood in the right chambers of the heart.

¹⁵ Spiegelberg, Würzburger Medicinische Zeitschrift, vol. v., p. 153.

¹⁶ Lehrbuch der Geburtshilfe, 1872, p. 593.

¹⁷ Schroeder, op. cit., p. 593.

The foramen ovale was patent and the structure of the heart otherwise normal. Numerous patches of extravasated blood were observed under the pulmonary pleuræ. On section the lungs were seen to be much congested and presented numerous "apoplexies," varying in size. When placed in water they sank immediately to the bottom of the vessel. The highest point of the diaphragm was on a level with the sixth rib; the liver and spleen were darkly congested and the rest of the abdominal contents healthy. The vessels on the surface of the brain were also much engorged with venous blood, but that organ was otherwise healthy, and on section the puncta cruenta were not very numerous. This may be regarded as an average example of the pathological conditions which characterise these cases, although Schantz, as I think somewhat theoretically, endeavours to discriminate between stases primarily due to attempts at intra-uterine respiration and those attributable in the first instance to compression of the funis, and even distinguishes mixed cases in which both these factors play a part.¹ It is conceivable, as he suggests, that in perfectly apnœic cases (which are rare), in which the cord is compressed, the vascular pressure may be first raised in the systemic arterial system, but we must not forget that such compression not only prevents the outflow by the umbilical arteries but also diminishes the inflow by the umbilical vein, and that only a moiety of mature fœtus will, under the circumstances, refrain from those attempts at respiration which attract the blood lungwards. Hecker² found much the same pathological conditions in six necropsies which he relates. Doubtless at times the pathological evidence of vascular engorgement, including the effusion of blood, is more pronounced in some parts than in others, and the locality of such serious derangement is important as determining the probable recovery of the child from the condition of apparent death. Thus Schultze³ mentions effusions of blood on the surface of the brain and into the spinal canal, as well as into the intestines. It can be readily understood how a considerable effusion into the

¹ Pflüger's Archiv für die Gesamte Physiologie, November, 1888, p. 264.

² Verhandl. der Gesellsch. f. Geburtshilfe in Berlin, Heft 7, p. 112, 1853.

³ Gerhardt's Handbuch der Kinderkrankheiten, vol. ii., Art. Asphyxie

latter may be comparatively harmless, while much less in the former situations may prove fatal. Attempts at respiration in utero, in the absence of air, necessarily result in the aspiration into the air passages of the uterine contents, including it may be meconium. The very presence of the latter in amniotic fluid is regarded by some as evidence of an advanced stage of asphyxia neonatorum, except in those cases, such as breech presentations, in which mechanical squeezing can account for it. The aspiration of this material may determine the ultimate issue of a case by provoking an irritative pneumonia by occlusion of the smaller bronchi or bronchioles. "In rare cases," Schultze remarks,⁴ "there is no proof of aspirated substances, in which case we must suppose that the intra-uterine respiratory movements have taken place with obstructed respiratory openings. In these cases the blood distribution, especially capillary extravasations, are particularly well marked. If these also are absent the rarest event has been reached—namely, that the dead child has made no respiratory effort." The fact also—which the experience of many must have taught them—that children are frequently born of normal colour and activity who give evidence (bronchial râles) of having attempted to breathe before birth also proves that such attempts do not necessarily involve asphyxia. As Schultze⁵ says, "there is an asphyxia without intra-uterine breathing and an intra-uterine breathing without asphyxia." In other words, in the former case death has begun at the respiratory centre, and in the latter threatened suffocation has been averted. It cannot be doubted, also, that even extravasations of blood of a serious character must be capable of absorption, and the child of resuscitation and restoration to life and health, when we consider the frequency of a grave degree of suspended animation in the newly born, in whom the intra-uterine conditions must have been such as to cause some of the changes discovered after death in those who are stillborn. The general cause of these phenomena of obstructed circulation may be said to be, in great measure, interruption to the systemic outflow ; but the argument from the adult to the foetal circulation is not altogether applicable. In the foetus, in addition to the propulsive force of the heart there

⁴ *Loc. cit.*, p. 21.

⁵ Virchow's Archiv, vol. xxxvii., p. 113.

is the purely hydrostatic influence of an elevated source of the circulating fluid—namely, the placenta. The pulmonary circulation, also, is undeveloped, and therefore a purely retrograde explanation of the thoracic subserous extravasations is insufficient. The failing heart, and, in cases of compressed cord, the interrupted arterial outflow, may account for excessive repletion of that organ and the venous system generally, but do not suffice to explain all the phenomena observed.

Krahmer,⁶ who was one of the first to note and to explain the pulmonary changes, but whose original work I have been unable to consult, gives a simple and fairly sufficient explanation of them, which is quoted by Hecker,⁷ to the effect that “under normal circumstances, on each inspiration, air and blood stream at the same time into the lungs, induced by the widening of the chest. If, now, inspiratory movements take place without the entrance of the former, the disproportion between the volume of the air passages and the capacity of the thoracic cavity is equalised to a certain extent by a more powerful access (*Zufluss*) of blood, and, on account of the thin walls of the capillaries, some burst, and blood in small quantity escapes, and this agrees with the fact that neither in adults nor in larger children is anything of the kind observed.” This argument is also rather strengthened by the fact that the nearest approach to such a condition in larger children is the minute injection of serous surfaces observed after death in cases of cardiac malformation with cyanosis; subserous extravasations may, however, take place under other circumstances, as when sudden death takes place in heart disease. But in the latter instances these are by no means so constant or widespread as in asphyxia neonatorum. Schautz, also, still guided by the supposed closure of the ductus arteriosus on attempted respiration, accounts for these ecchymoses by the raised pulmonary vascular pressure.⁸ Schultze's argument⁹ assumes a diminution of external pressure (*Aussendruck*) on the total thoracic contents, a fall of pressure in the heart and vessels within the chest, a draining of the systemic vessels in the aortic territory, and he says that “the capillaries of

⁶ Handb. d. Gerichtlich. Med., 1851.

⁷ Loc. cit., p. 158.

⁸ Loc. cit., p. 264.

⁹ Loc. cit., p. 17.

the lungs alone, which in the total expansion (Ausdehnung) suddenly find themselves amid the lessened external pressure, become full."

I found myself most in accord with Krahmer's simple hypothesis, but, in order to determine the point more satisfactorily to myself, devised the experiments to be presently related. While aware of the rough-and-ready character of such schemata of the circulation, and of the fallacies possible in argument from the artificial to the natural, I would submit that the hydraulic as apart from the vital elucidation afforded by experiments with models is not without value and interest. Thus, from experiments with the sheep's heart and a simple arrangement of glass and indiarubber tubes I came to the conclusion that the aspirative power of the left ventricle after injection of the coronary system with water was 120 mm., and that of the right 30 mm.¹⁰ This gives a relative negative pressure of right to left ventricle of 1 : 4. In the dog, Foster¹¹ states the intra-ventricular negative pressure as -52 to -20 mm. for the left and -17 to -16 mm. for the right ventricle, which, taking the maxima, yields a ratio of right to left ventricle of 1 : 3, a sufficiently close approximation to the results given by the dead heart and apparatus to impart a certain value to that simple method of investigating the purely mechanical factors. Von Basch indeed, has recently written an exhaustive essay on questions of cardio-vascular physiology and pathology based upon experiments made with a model of the circulation.¹² Goltz and Gaule also bear testimony to the experimental value of the model in their well-known paper on intra-ventricular pressure in vol. xvii. of "Pflüger's Archives." The experiments, therefore, which I have made—in the manner to be described—have led me to modify my unreserved adhesion to any of the theories which I know to have been advanced in explanation of the phenomena in question. Of course, all the factors which play a part in [the transformation of the intra-uterine into the extra-uterine circulation have their own place and influence. The question we have to determine is the relative power of these factors in the mature foetus and newly-born infant, and also in what

¹⁰ Dextral Valvular Disease, p. 36.

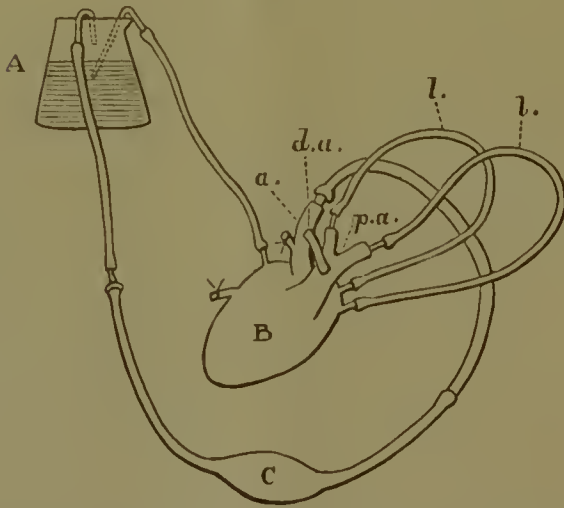
¹¹ Physiology, p. 145.

¹² Allgemeine Physiologie und Pathologie des Kreislaufes.

manner the influence of the most powerful, as the most important and vital of them, is to be fostered. Before we can do so we must naturally come to a conclusion as to the relative power of the factors concerned.

Experiment 1. (Fig. 1.)—In a sheep's heart (B) the curtain of the foramen ovale was removed. A piece of rubber tubing with the ends cut so as to occlude the lumen of the vessels as little as possible was inserted between the pulmonary artery and aorta just below the obliterated cord of the ductus arteriosus, and retained in position by sutures. The inferior vena cava was ligatured and a piece of glass tubing

FIG. 1.

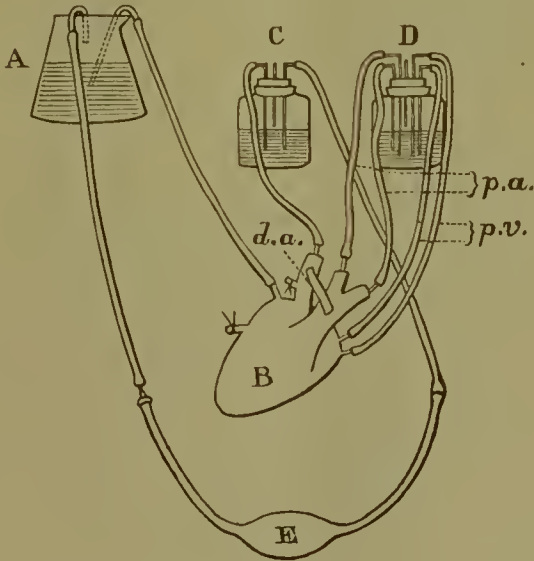


tied into the superior cava. Glass tubing was also tied into the two main branches of the pulmonary artery and into the pulmonary veins, and then these were connected by two pieces of rubber tubing. A piece of lead gas-pipe was tied into the free end of the aorta and the innominate artery ligatured. The proximal end of a Higginson's syringe (C) was then attached to the aorta, while the distal end of the syringe was continued by rubber tubing into a water-jug (A). The latter, representing the placenta, was placed at a higher level than the heart. On establishing the syphon by suction with C a few points in the vessels and auricles jetted, but were

secured by ligatures, and the apparatus was rendered practically watertight. It was then found to work quite well, the heart being emptied by the diastole of the syringe and filling during its systole. The pulmonary artery filled immediately after expansion of the syringe first, and emptied last, the chief force of suction by C being felt by the aorta, which gained its main supply of fluid by way of the artificial ductus arteriosus.

Experiment 2. (Fig. 2.)—D is a glass jar with four glass tubes passed through its cork for attachment to the pulmonary arteries and veins, and has a central tube for air.

FIG. 2.

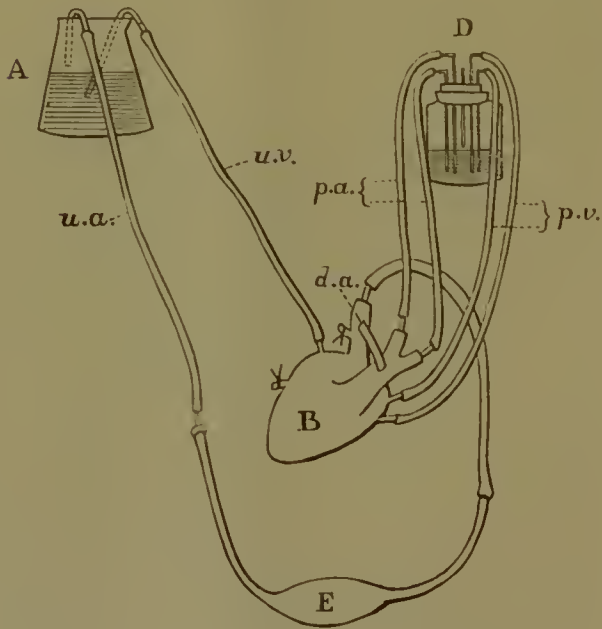


The jar represents the lungs and is filled by syphonic inflow more rapidly than C, another glass jar, having two tubes through its cork for attachment on the one hand to the aorta and on the other to the tubing representing the systemic arterial system. A central tube is also inserted through this cork to afford normal atmospheric pressure. In this experiment C emptied rapidly under the influence of the syringe (E), while the water in D was practically uninfluenced by the

latter, showing that the aspirative force of E was incapable of affecting the fluid in D, representing the pulmonary circulation.

Experiment 3. (Fig. 3.)—If, however, the jar (C) be removed from the circuit and arterial connexion be made directly with the aorta, as in Experiment 1, D is slowly emptied by the action of E, which exercises its principal influence upon the aorta by sucking water through the arti-

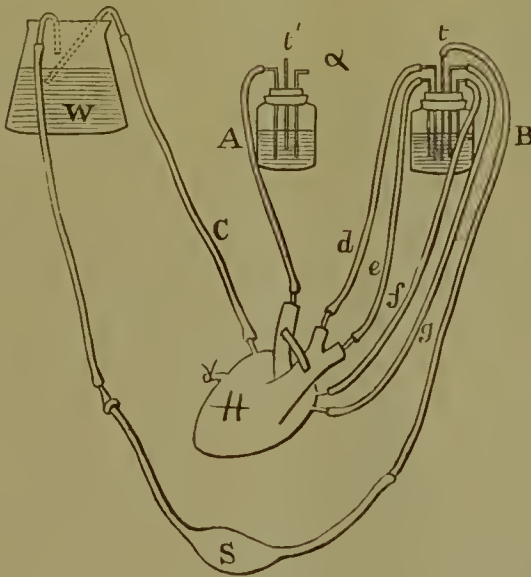
FIG. 3.



ficial ductus arteriosus, but also upon the aorta proper to a less extent. In other words, the action of the foetal left ventricle has little effect upon the pulmonary circulation. The diastole or filling of the syringe (E) of course coincides with the emptying of the ventricles, and its systole with their filling by the syphon established; but, nevertheless, the negative pressure in the diastolic syringe likewise causes a diminution of pressure in the chambers of the heart.

Experiment 4. (Fig. 3.)—If uv , representing the umbilical vein, be compressed, no fluid enters D. If uv and ua , representing the umbilical arteries, be compressed after fluid has been allowed to enter D, the latter remain stationary. If uv be compressed and E worked, fluid is removed comparatively quickly from D. If uv and ua be left uncompressed and E be worked, fluid enters D more quickly than it can be removed by E. If ua be compressed, there is an increase of tension or of pressure first felt by E and the arterial system, and the action of E in evacuating D is arrested. If under these circumstances uv be also compressed, the water level in D remains stationary after the fluid has gained its proper level by percolation through the various cardiac and pulmonary vascular openings—that is, compression of the cord in nature implies arrested inflow as well as outflow.

FIG. 4.



Experiment 5. (Fig. 4.)—In this experiment the syphon action from W was established by the syringe S effecting a partial vacuum in B t, when fluid passed very readily into B, but did not sufficiently enter A for the purpose of the expe-

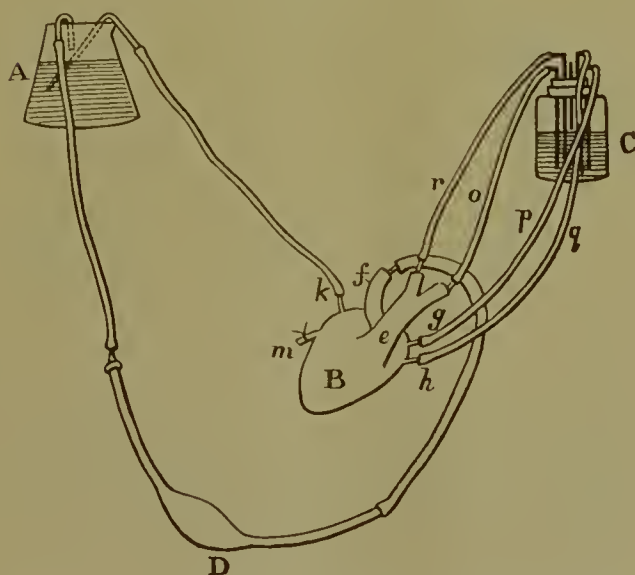
riment. This may be taken to have represented the effect of full pulmonary respiration in closing the ductus arteriosus. While the stream through the established syphon was running towards B, the syringe had to be temporarily attached to A t' to fill it sufficiently by way of the artificial ductus arteriosus for experimentation. When a sufficiency of fluid had accumulated in both A and B, the syringe S was again attached to B t and the heart, H, raised so as to prevent the fluid in A and B returning to a lower level. C, representing the umbilical vein, was then grasped to prevent the entrance of more fluid into A and B by way of H. When, now, a partial vacuum was effected by means of s in B, fluid in all vessels directly and indirectly connected with B was urged towards the vacuum, because there was no sufficiently powerful counteracting vacuum in H such as would in some degree have been produced by attaching a syringe to A t and closing A a, representing the systemic arterial circulation. As I argued on a former occasion,¹³ the aspirative power of left ventricular diastole (negative pressure) is great to overcome the retentive power of the thoracic vacuum, and as during each respiratory act this diastole occurs about four times this number seems necessary to maintain the continuous flow of the pulmonary blood pumped into the lungs by an equal number of systolic contractions of the right ventricle, aided by thoracic action. The effectiveness of diastolic aspiration in a particular direction is in proportion to the absence of openings through which aspiration can be exerted in other directions. The diastolic aspirative power of the left ventricle is diminished in the fœtus by the presence of the foramen ovale kept permanently open by the preponderant pressure in the right auricle and by the smaller capacity of the ventricle itself, which has less propulsive power than it has extra uterine. In the adult, therefore, a single respiration has probably the retentive power of about four left cardiac diastoles, and suction is related to the size and perfection of the vacuum. In the fœtus the absence of a pulmonary thoracic vacuum does away with the necessity for a counteracting left ventricular aspiration, but attempts at respiration have on this account a more lasting attractive force, although, as I shall have occasion to suggest presently, the current from the pulmonary artery into the

¹³ Dextral Valvular Disease, p. 38.

aorta through the ductus arteriosus may have some influence in correcting minor degrees of repletion of the pulmonary vascular system in the fœtus.

Experiment 6. (Fig. 5.)—The inferior cava (*m*) is tied; the inflow is from *A* through the superior cava (*k*); the ductus arteriosus, between the pulmonary artery (*e*) and the aorta (*f*), is obliterated; the foramen ovale is still unclosed; *C* is the lung bottle with inflow through the pulmonary arteries (*r*, *o*) and outflow through the pulmonary veins (*p*, *q*); *D* is the

FIG. 5.



syringe. On establishing the syphon, *C* filled much more rapidly than it could be emptied. Indeed, vigorous action of the syringe, which was difficult from its tendency to collapse under external air pressure (the "Aussendrück" of Schultze), could only slightly arrest inflow into *C*. This could be done somewhat better on substituting a powerful brass syringe for Higginson's. The effect was thus in proportion to the aspirative power, and accumulation or stasis was therefore dependent upon defective outflow along systemic vessels. The closed ductus arteriosus in this experi-

ment had an appreciable influence in maintaining the fulness of C. In Experiment 3 the lung bottle could be slowly emptied by the syringe, but not so here. In that experiment this must have taken place in a measure by retrogression of the fluid down *r* and *a*, as well as from diversion of the flow towards the lung bottle by the action of the syringe upon the ductus arteriosus. In nature this cannot occur, from the action of the diastolic right ventricle when the pulmonary valves are perfect, but it is conceivable that the removal of engorgement due to attempted respiration

FIG. 6.



in utero may to a certain extent be effected by the attractive influence of the onward current through the reopened or widened ductus arteriosus. Is then the occurrence of lung ecchymoses due mainly to closure of the ductus arteriosus, as Schantz argues, or chiefly to defective action of the left ventricle? This remains to be considered.

Experiment with the perfect heart was not made, because deemed unnecessary after the results of Experiment 6. It could only have shown a slightly improved left ventricular aspiration. Injecting the coronary circulation would also have increased the capacity of the chambers of the heart and thus have facilitated relief of stasis in the lung bottle, but the action of the syringe would have tended to aspirate fluid from these vessels, and their injection was not therefore undertaken.¹⁴

¹⁴ I subsequently performed the experiment with the adult and uninjured sheep's heart, and used alternate manual compression and relaxa-

Experiment 7. (Fig. 6.)—If now, instead of using the natural heart, a Higginson's syringe (B) be made to represent the right heart, and another, D, the left heart, the former pumping water into the lung jar A at each compression, and the latter withdrawing it at each expansion, the fluid will rise and fall rhythmically like an equal respiration, as much water being abstracted as flows in, and no over-accumulation taking place.¹⁵ By closing the central neck *t*, representing the trachea, and thus increasing external pressure, the phenomena of pulmonary congestion and plethora of the venous system may also be demonstrated with this apparatus, the fluid accumulating more rapidly in the lung bottle than it can be removed; while the readmission of air, with lessening of external pressure, again restores the balance of the circulation¹⁶ and allows of the removal of excessive accumulation in the jar representing the pulmonary circuit. The latter part of this experiment, however, applies rather to extra- than intra-uterine respiration. The new-born child which cries lustily immediately after birth, even when the cord is pulsating powerfully, does not become cyanotic either before or after the cord is tied. The left heart is capable of dealing with the inflow of blood from the placenta by way of the right heart, as the syringe (D) in Experiment 7 can deal with the water in the lung bottle, although there is reason to believe that for some days the whole of the blood sent during foetal life through the ductus arteriosus to the aorta and that passing through the foramen ovale into the left ventricle are not at once diverted towards

tion as the motive power after filling the lung-bottle by syphonic inflow through the right heart. The aspirative power of the left ventricle was found to be greater when the coronary arteries were filled with water *per aortam* than when these were empty; but it was difficult by this means alone to establish the circulation from the lung-bottle to the left heart. When, however, somewhat more powerful aspiration was applied to the tubing representing the pulmonary veins, and syphonic inflow was thus established, alternate compression and relaxation of the left ventricle caused water to be ejected *per saltum* from the aorta. This experiment proves the important rôle of the passive forces of gravitation in the circulation, as distinguished from the active forces of aspiration and propulsion—forces which render the latter not only more easy, but possible. The thoracic expansion due to the initial act of aerial respiration in the newly-born raises at once the blood to a higher level relatively to the left heart, and induces its more copious and powerful flow into its chambers. Pulmonary aspiration and circulation in the adult heart is thus equivalent to the higher hydraulic inflow from the placenta in the case of the fœtus. This fact is of general therapeutic interest.

¹⁵ *Ibid.*, p. 41.

¹⁶ *Loc. cit.*

the lungs. The latter orifice is, however, probably more perfectly closed than the former. What, then, are the factors which so readily transform the foetal into the extra-uterine circulation? And what is their relative power or importance? With the act of aerial respiration there is a great increase of thoracic capacity, with lessening of extra-thoracic pressure, although this increase may not immediately reach its greatest extent. Hermann has demonstrated by a very simple caoutchouc apparatus and air pump¹⁷ that such a thoracic increase implies not only pulmonary but also, to a less extent, cardiac expansion. This has also been observed at high altitudes and in a rarefied atmosphere in the case of the human heart. The large diversion of the blood current lungwards lowers pressure in the right chambers of the heart, commencing with the right auricle. The auricles, being thin, also probably respond to the influence of lessened external pressure more readily than the ventricles.¹⁸ The stretching of the ductus arteriosus described by Schantz¹⁹ narrows that channel, which, nevertheless, for a time remains pervious and permits of the passage of blood. Increased cardiac capacity involves increase in the capacity of the left auricle and ventricle, and the latter especially is enabled to exercise all its increased aspirative power on the pulmonary circulation, because, unlike the valveless ductus arteriosus, blood entering the left auricle finds a perfect valve over the left side of the foramen ovale, more than sufficient to close it, and capable of instant and perfect closure, although not yet permanently sealed. The fall of intra-cardiac pressure in the right chambers favours this perfect closure of the foramen ovale and thus fosters more remotely the influence of the negative pressure of left cardiac diastole. In addition to the mere prevention of reflux from the left auricle, and in addition, also, to its increased capacity, there must under these circumstances be so notable a fall in left intra-auricular pressure that the comparative vacuum so created must at once give an impulse *a fronte* to the pulmonary circulation held in comparative abeyance while the full force of the blood current, directed by the Eustachian valve through the foramen ovale into the left auricle, was in operation. Marey²⁰ concludes, without

¹⁷ Text-book of Physiology, translated by Gamgee, p. 160.

¹⁸ Hermann, *op. cit.*, p. 160; Broadbent, *The Pulse*, p. 128.

¹⁹ *Loc. cit.*

²⁰ *Circulation du Sang*, p. 115.

direct experiment, that the left and right intra-auricular pressure are practically the same and gives the maximum pressure in the right auricle of the horse as 2·5 mm. In not determining the left intra-auricular pressure he remarks that the difficulty of doing so seems to exceed the importance of a parallel determination. That the difficulties are great must be conceded ; but that the importance of accurate knowledge in this matter is unimportant may be questioned. Considering the great size of the vessels entering the right auricle as compared with those which enter the left, and also the notable difference in the positive and negative pressures of their respective ventricles, it is legitimate, even without positive evidence, to conclude that the left must be considerably less than the right intra-auricular pressure. Both in the newly-born infant and in the adult we regard this very probable fact as of the highest importance in its scientific and practical bearings. A satisfactory thoracic vacuum brings this factor into play.

Waller²¹ states that "the maximum systolic pressure in the left and right auricles amounts to about 5 and 2 centimetres of mercury respectively." It is not stated by what method of experiment this calculation was obtained ; but as the negative is proportionate to the positive pressure it follows that the negative pressure, or suction power, of the left auricle must be greater than that of the right auricle. As, moreover, the negative pressure in the right ventricle, corresponding to a positive pressure of + 6 cm., is - 1·5 cm.,²² it is fair to infer that the negative pressure, corresponding to + 5 cm. in the left auricle, is about - 1 cm., while that in the right auricle, corresponding to + 2 cm., is less than - ·5 cm., or practically inappreciable, and of little suction power. Any method of investigation, however, such as the passage of a manometer sound through the mitral valve, would, we believe, vitiate the result by transmitting during systole some of the left intra-ventricular pressure to the auricle. On *a priori* grounds, and from anatomical considerations, we should have expected to find a permanent lowness of pressure in the left auricle under normal circumstances.

As Dr. Robert Barnes remarks, "it is one of the most remarkable and gratifying illustrations of the phenomena of respiration and circulation to observe how quickly the bloated,

²¹ Human Physiology, p. 64, 1893.

²² Waller : *op. cit.*, p. 64.

cyanosed aspect of the face vanishes, giving place to a healthy hue when a good respiration takes place.”²³ Now, to throw more blood into an imperfectly expanded lung, incapable of perfect relief by left cardiac action, would be but to engorge it were the ductus arteriosus closed. When, therefore, Schantz regards the beneficial action of artificial respiration in asphyxia neonatorum as mainly due to that manœuvre closing that foetal channel, we believe, to use a homely phrase, that he places the cart before the horse and sacrifices reason and the teaching of experiment (Erichsen) to a pre-conceived notion. There can, however, be no doubt that every production of thoracic vacuum, natural and artificial, causes an increased flow of blood into the heart by way of the venæ cavæ, and we are inclined to believe that the considerable quantities of serous fluid found in the pleural and pericardial cavities in some of these cases—as, for example, in the one which I have related—is due also in part to the influence of direct aspiration during attempted respiration, as well as to the passive relief which follows plethora.

The act of respiration, then, with lessened external pressure and expansion of all the thoracic contents, we regard as of the first importance—as the most powerful factor in the development of aerial respiration. As the particular event next in power and importance to this we should place the increased capacity of the left cardiac chambers, especially the left ventricle, and the perfect closure of the foramen ovale from within and the fall of pressure in the left auricle. As the last and least important factor under normal circumstances we consider the narrowing of the ductus arteriosus. It is, in fact, important that the latter should *not* be closed for some days, and we believe there is evidence, anatomical and physiological, that it is not so closed. This argument is supported, moreover, by a study of cyanosis due to cardiac malformation. The communication which in such cases exists between the chambers of the heart and between the ventricles or auricles, or both, diminishes the aspirative efficiency of sinistral negative pressure and the normal repletion of the arterial system. With this, progression in the pulmonary circuit and in the systemic capillaries alike is impeded. The latter may be

²³ Obstetric Med. and Surg., p. 165

shown by sphygmographic tracings,²⁴ the former by physical examination of the chest. The obstruction being thus extra-cardiac, it is a matter of little surprise that examination of the heart by auscultation should in these cases so often give a negative result. As in the case of the foetus, the impediment within the heart is often, we should say usually, not such as to originate bruit. The foetal heart has no bruit either in utero, or in conditions of suspended animation extra uterum in which foetal channels remain open, as in most cases of cardiac malformation. Dr. Walshe²⁵ has endeavoured to indicate the probable signs of a persistent ductus arteriosus in the adult, but confesses he does so on purely hypothetical grounds.

Although thus, under normal circumstances, the last and least important of the events involved in the beautiful circulatory transformation which takes place after birth, it does not follow that the condition of the ductus arteriosus is of little importance in utero. The temporary and partial diversion of the circulation lungwards on attempted respiration must rob the ductus arteriosus of its full complement of blood without materially affecting the other factors in the circulation. The increased blood-flow into the lungs, meeting with impediment in front from an insufficiently accelerated current due to defective left cardiac aspiration and propulsion, puts a pressure upon the pulmonary capillaries which they cannot withstand. Hence (except in the case of very transient plethora of the proximal portion of the pulmonary circuit) subserous extravasations of blood and bleeding into the lung tissue ensue. The cause, then, on this showing, of the characteristic ecchymoses of intra-uterine respiration is thoracic aspiration, unaccompanied by sufficient left cardiac action and associated in all probability with a minor degree of narrowing of the ductus arteriosus, which cannot, fortunately, be quite closed. The partial closure of this channel must be of a very transient character, because on post-mortem examination it is found to be patent, and there is often said to be a fairly equal distribution of blood in the right and left chambers of the heart from percolation after death.

²⁴ Morison, *The Practitioner*, March, 1888.

²⁵ *Diseases of the Heart*, p. 567.

V. CLASSIFICATION.

We have now to consider an important clinical distinction in the stages of this condition, which has for long been impressed upon observers by experience, and probably upon many who, though struck by the notable difference in the general appearance of these cases, have not investigated in any exhaustive manner the anatomical and physiological factors which underlie asphyxia neonatorum livida and pallida respectively, or the "blue," "apoplectic" or "cyanotic," and the "pale" or "anæmic" cases of apparent death in the newly-born. Barnes divides these cases into three groups, with the first two of which we are at present mainly concerned. These are, firstly, "simple asphyxia," by which he denotes the livid variety, and which he attributes to interrupted hæmatosis or arrest of placental respiration before the establishment of lung respiration. Interrupted hæmatosis doubtless plays an important part in both varieties, but so general a cause cannot account for the fact noted by Cazeau¹ and generally admitted, that the cyanotic tint is most perceptible in the upper portion of the body, and especially in the face. This is indicative of local anatomical influences. Just as the "intermixture theory" of cyanosis from cardiac malformation has given place in great measure to the "obstructive theory," so also must the rôle of defective hæmatosis be a comparatively limited one in the production of the cyanosis met with in the first stage of asphyxia neonatorum. Barnes' second group he terms "paralytic asphyxia," or that in which respiration is prevented by incapacity of the nervous centres. In his third group he includes "atelectasis," due to imperfect development. As "atelectasis" and "apneumatosi" have much the same significance, I presume that Barnes refers in his third group to the persistent atelectasis associated with congenital local defects in the heart or lungs, otherwise the creation of this category is scarcely called for, as atelectasis may be a feature of the two preceding classes; this, however, I say with diffidence, as criticising the classification of one for whose genius I have the most profound respect. Schnltze² makes the presence or absence of muscular tonus a criterion. It is present in the livid, absent in the pale variety. These he regards as the

¹ Gazette Médicale de Paris, 1850, p. 318.

² Loc. cit., p. 24.

first and second stages of one condition. The former is with justice regarded as, on the whole, the less serious, but it must be remembered that, although the primary or cyanotic stage may be that from which recovery is most easy, it is undoubtedly also that in which the prospect of recovery from the pale and more grave condition may be determined; for the lung, and possibly other organs, may be so damaged in the first stage in utero, from blood engorgement and extravasation, as to render recovery from the second stage after birth impossible. Although, therefore, the apparently dead "cyanotic" child, and the "pale" child in the same condition, may represent different stages of one kind of disorder, it does not follow that the etiological factors within the foetus are the same in both cases, and therefore the conditions underlying them may—and, I believe, do—differ. In the earlier stage the child has a more sentient central and local nervous system, more vigour, greater respiratory power, and makes more powerful efforts to breathe. It is, in short, apparently less dead. Hence it diverts the blood current more powerfully lungwards, causing stagnation in a comparatively active afferent circulation from the mother when still attached, which the foetal heart with diminished outlets (ductus arteriosus and, less probably, foramen ovale) fails to dispose of. Thus it is that congestion with lividity is most evident in those regions in which the foetal circulation is most active, and which, it must be remembered, are in utero also usually most dependent, as the diagram in my previous article shows.³ In the more advanced, or pale, stage the nervous system, and with it the heart, have practically given up the struggle; respiratory effort is much feebler, if made at all, and such blood as is derived from the sluggish afferent current when the cord remains uncut, and which still circulates, finds its way unimpeded through the gaping foetal channels and orifices towards the outlet of the aortic system in the umbilical arteries, or is, in other words, more equally distributed.

Except in the case of cyanosis due to cardiac malformation, the newly born child rarely dies in the livid stage of asphyxia. As a rule it dies pale. It is known that even well-marked cases of true cyanosis become paler after death,⁴

³ THE LANCET, Feb. 24th, 1894.

⁴ Walshe: Diseases of the Heart, fourth edition, p. 422.

just as they frequently become more livid on coughing or on other interruption to respiration during life. Feebleness and death are indeed always paler than preceding conditions of greater vigour and of life; it is not remarkable, therefore, that the post-mortem appearances should be much the same in all fatal cases. Some, even of these, however, such as the lung ecchymoses, represent an ante-mortem phase of more vigorous struggle for life, and, could the child be examined anatomically in this earlier stage, stasis unrelieved through the foetal channels would be more pronounced than in the later pallid, and more powerless, stage of this condition. Lividity and pallor, therefore, denote less a total excess or deficiency of blood in the foetal body than, in the former instance, an unequal, and in the latter a more equal, distribution of it; while the total amount is influenced as much by the arrest of the afferent stream through the umbilical vein as by any loss through the umbilical arteries. Both gain and loss are influenced by the action of the foetal heart. The heart, which attracts little blood, loses little, and *vice versa*. In the latter case it can afford to lose more than in the former. As, therefore, the state of the heart's action is the most valuable indication of the vitality of the child, I should feel disposed to divide cases of asphyxia neonatorum into (1) those in which the foetal channels are narrowed and there is an obstructive plethora of the venous system, with cyanosis; and (2) those in which the resistance of the foetus has been overcome and the relaxed foetal channels permit the languid blood stream to find its way without such impediment as to engorge the surface. With anatomical and physiological amplification this is merely a reversion to the oldest division into asphyxia neonatorum livida and pallida, or the "blue" and "pale" varieties of apparent death in the newly born — terms which imply all the other conditions which have been selected by different writers for the purposes of classification.

VI. PROGNOSIS.

From the facts already mentioned and the argument based upon them it will be readily understood why in this, as in all other disorders, the prospects of recovery are better in the earlier than in the later stage of asphyxia neonatorum. It has also been mentioned, however, that, even

in the earlier stage, should pulmonary conditions arise and blood extravasations in the lungs or elsewhere occur, more especially within the cranial cavity, they may prevent the permanent recovery of the infant even after aerial respiration has been established. The situation of conditions causing intra-cranial pressure is of varying import. It is generally agreed that considerable effusions on the surface of the hemispheres may be tolerated with comparative impunity, while much less at the base of the brain may prove fatal. This agrees with that which must have occurred to many to observe—namely, the great degree of pressure the hemispheres will tolerate when, for example, in forceps delivery, deep impressions have been made upon the skull of the foetus. I have myself produced such an impression upon the upper portion of one frontal bone from forceps delivery through a kidney-shaped, rachitic pelvis, large enough to have afforded a hen's egg a steady resting-place, without apparently doing the child any harm immediately or subsequently. The impression levelled up. Unless, therefore, it affect a vital part, it does not appear to be so much the *degree* as the *duration* of pressure incurred in the "accidents of childbirth" which seems to influence recovery in these cases. Too great force, even temporarily applied, as in podalic version, may break the foetal neck, or, similarly, excessive pressure exercised on the foetal head may determine a fatal issue in cases which might otherwise have survived. To these points I shall have to recur in discussing the preventive treatment of asphyxia neonatorum.

Speaking generally, the best guide to prognosis will be found in an examination and estimation of the cardiac power of the asphyxiated infant. Asphyxia (*a*, privative, and *σφύξις*, the pulse) has in these cases its literal meaning—not suffocation, but *pulselessness*. The degree of pulselessness ascertained by auscultation of the heart is the best guide to prognosis. Barnes⁵ remarks that he is unaware "that recovery has ever been established when the heart has ceased to beat." That this should be so in the case of the newly-born infant and not in the case of those with a fully developed aerial circulation, as appears to be the case in some instances of profound syncope, is easily understood when the imperfect aspirative power of the left chambers of the heart in the

⁵ Obstetric Medicine and Surgery, p. 159.

former is borne in mind. To this point also, as having a very important bearing upon a satisfactory theory of the mechanism of artificial respiration, I shall have to refer when dealing with the treatment of asphyxia neonatorum. The frequency, power, and regularity of the heart's beat must therefore guide us in prognosis. If these be considerable we may augur well of the prospects of the infant, provided no effusion in a critical neighbourhood has taken place or any injury of a necessarily fatal character been sustained during labour. So much for prognosis as to immediate consequences.

The remote effects of asphyxia neonatorum are chiefly those which are understood by the term "atelectasis," but in this category may also with justice be placed some cases of death regarded as due to "naval hæmorrhage." Barnes⁶ quotes "Ploucquet, Bandelocque, and others" as having shown that a disposition to umbilical hæmorrhage could be induced by interrupting the respiration of the newly-born child. It is probable also that some of the registered cases of death from "diseases of the respiratory organs" occurring during the first month of life, and a considerable proportion of the large class noted as having died of "atrophy," and some even of those ascribed to "convulsions" and "diseases of the nervous system" within the same period have their origin in the perverted conditions involved in asphyxia neonatorum. It may then be asserted with good reason that the more severe asphyxia neonatorum—the more difficult the removal, that is, of the conditions maintaining this state, whether in lungs, pleuræ, heart, brain cavity, or abdomen—the worse are the prospects of perfect recovery. When violent efforts have been made to breathe by the fœtus in utero the greater is the risk of the aspiration of foreign substances into the bronchi and bronchioles, with permanent occlusion of these, and the greater also the risk of the production in a pronounced degree of the circulatory disorders of which mention has already been made. The duration of the influence of the latter will be in proportion to their severity and situation. Dr. W. J. Little⁷ refers some cases of spastic rigidity, paralysis, and idiocy to the remote effects of asphyxia neonatorum.

⁶ Op. cit., vol. II., p. 122.

⁷ Transactions of the Obstetrical Society, vol. iii., p. 293.

VII. TREATMENT.

The preventive treatment of asphyxia neonatorum consists, firstly, in promoting the vitality or viability of the fœtus; or, the more vigorous it is, the less likely is it to succumb to the accidents of parturition. Measures directed to this end might, perhaps, be more correctly termed the preventive treatment of *asphyxia nascentium* than of *asphyxia neonatorum*. The next object is to endeavour to avert asphyxia when threatened in the course of labour. The former is largely a medical and gynæcological question; the latter entirely one for obstetricians. The vitality of the fœtus in utero may be threatened by those causes which have already been briefly mentioned, and treatment consists in following the indications afforded by them. The anæmic must be fed and given hæmatinics, with or without the addition of chlorate of potassium, in which the experience of some causes them to have faith. Specific treatment with mercurials, iodide of potassium, and iron has frequently yielded good results in syphilitic cases. One remarkable instance of this I have referred to. In addition to the general or constitutional remedies, the correction, so far as possible, or cure, of any local and concurrent disease will demand the attention of the physician by recognised means. In association with such remedies, in the majority of cases, functional and mechanical rest, sometimes for a length of time, will be necessary, and especially in cases in which accidental hæmorrhage shows a tendency to premature separation of the placenta. Shock of every description must also be avoided as far as possible in all cases, and especially in those in which a history of abortion reveals a difficulty in the production of mature children. Into the obstetric question this is not the place to enter in detail. It consists mainly in the care of the umbilical cord if it be jeopardised, and in the timely and skilful delivery of the fœtus. Skill will, in this case, consist of rapidity in delivery without undue force either as affecting the maternal passages or the fœtal body. Among preventable causes Schnltze⁸ very wisely calls attention to the necessity for caution in the use of ergot in tedious labour, and to the need of the accoucheur being prepared to act promptly should the drug produce its oxytocic effect without a corresponding rapidity in the birth of the child.

⁸ Loc. cit., p. 32.

The question of the attendance upon parturient women of midwives is an important one. The convenience to the practitioner having charge of a practice scattered over a wide area of having the assistance of a midwife in whom he has confidence, and who is able to relieve him of personal attendance upon a certain number of normal labours, is, no doubt, very great ; but, unless such an assistant be capable, in addition to her other duties, of gauging the state of the foetal vitality, it may be questioned whether she be not an anachronism in a civilised country. Unless she be capable of using the stethoscope to estimate the condition of the foetal circulation she cannot be considered as fully equipped for her position. I am not aware that she ever possesses this knowledge. The child unborn requires almost as much care as it does after birth. If without such knowledge it be permissible for the midwife to officiate *before* birth, it is certainly illogical to prevent the druggist from prescribing *after* birth. The use of the stethoscope should therefore be a portion of the midwife's training before any registration which may be insisted upon in the future. Now, although it is not impossible that an intelligent woman might learn enough of abdominal auscultation for her purpose, it is questionable whether so partial an education would not be an example of that taste rather than deep draught of the Pierian spring which would render her limited education dangerous rather than useful. If she cannot be sufficiently instructed in this matter (and personally I do not think she can be) a well-organised State should insist upon the services of a fully educated man or woman being alone permissible, who even then should be required to give a certificate of the probable causes of foetal death when this occurs during labour. Medicine is sufficiently advanced in the present day to make such a demand quite reasonable.

These preliminary considerations apart, the first question which arises in the treatment of asphyxia neonatorum when the newly-born infant is actually in the hands of the physician is, Should the umbilical cord, if pulsating, and with the placenta so far as can be determined still attached to the mother, be divided or left intact so long as the maternal connexion exists? As Barnes² says, it

² Op. cit., p. 160.

is not easy to answer this question absolutely. He mentions an instance in which the foetus in a case of placenta prævia had to be delivered between the sixth and seventh month, and which had the same acceleration of pulse after respiration, both before and after the cord was severed, and adds: "We here see that placental and aerial respiration were of equivalent value in maintaining the foetal pulse at ninety." The case, however, appears to be scarcely decisive of this point, for, although the infant was connected with the mother, its extra-uterine respiration was none the less aerial on that account. The case shows rather that the acceleration of the pulse under the influence of respiration was the same whether the child's heart was dealing with blood in its own body or with that in addition which it received from the mother, and some of which it got rid of by the umbilical arteries. Barnes, however, concludes that it is best to divide the cord at once and in any case. Cazeau, in treating the same subject,¹⁰ remarks that some persons have advised that in cases of asphyxia the cord should not be cut until the establishment of pulmonary respiration, but comes to the conclusion that not doing so is at best useless and even hurtful in losing precious time. In the later edition of Cazeau's "Obstetrics," edited by Tarnier and translated by Hess, Cazeau's earlier views remain unqualified; the opinions of these able obstetricians denote, however, a measure of uncertainty, and the question cannot be thus summarily dismissed.

The cardiac ventricle in the foetus, which is the chief agent in attracting and propelling the materno-foetal circulation, remains after birth the principal force in filling and emptying the pulmonary circuit. The question then comes to be, What influence will dividing or not dividing the umbilical cord in cases of apparent death in the newly-born have upon the cardiac ventricle? In utero we have mainly to consider the action of the right ventricle, extra uterum that of the left. The earlier the stage of gestation at which birth takes place, the more intimate and persistent is the attachment of the offspring to the parent. In a four months' foetus aborted alive I have observed active movement cease promptly on dividing the narrow cord. It was literally cutting the thread of life. The point to be settled before anything else is the

¹⁰ Gazette Médicale de Paris, 1850.

attachment or detachment of the placenta, and this can usually be rapidly done. If there has been no escape of blood to indicate detachment, and the uterine orifice be not occupied by some portion of placenta or bulging membranes, the after-birth may for a short time be assumed to be still connected with the uterus. Should there be any doubt upon this point, there is obviously no reason for delaying division of the cord. Pulsation in the cord means pulsation of the child's heart. If the cord pulse be good, the heart pulse will be found to be good also ; and under these circumstances only in exceptional cases will there be any delay in the establishment of aerial respiration. Even after the full development of the latter, as I have mentioned, the cord may be felt for a time to pulsate fully and vigorously—more fully and vigorously than before respiration, the more capacious left ventricle pumping more blood into it. While the heart pulse is good and the placenta remains attached the inflow through the umbilical vein fully compensates the child for any loss by way of the umbilical arteries.

If the fœtus be born asphyxiated and cyanotic, and the heart and cord pulsate fairly well, the inflow is in excess of the outflow ; and this is probably due to the rapid entrance of blood, on hydrostatic principles, being in excess of the disposing power of the fœtal heart. The impediment in such case is in the heart and lungs, for the fœtus has probably attempted to breathe before if not after birth. Under these circumstances the cord must be divided in order to prevent the inflow, and to enable the heart to equalise its income and expenditure it may be allowed to bleed more or less, according to the degree of cyanosis. If the cord pulse be weak and slow, the heart must correspond and needs immediate attention. This condition will not usually be found associated with a cyanotic tint, as enfeebled and slow propulsion means lessened attraction by way of the umbilical vein. Can the heart receive the attention necessary while the child is attached to the mother ? When the means necessary for resuscitation of the infant in this condition come to be considered, it will be apparent that this can rarely be done without dividing the funis. In view of the lessened inflow of placentally oxygenated blood it is, therefore, scarcely worth while postponing this operation under these circumstances. Again, on the first evidence of separation of the placenta the cord must be cut and tied if the

child be not cyanotic, as funicular pulsation then means some, although probably not great, loss of blood by the fœtus, as the inflow has naturally ceased. If in any case it be deemed advisable to leave the cord uncut for a time, while the hand of the accoucheur may gently feel the uterus through the abdominal wall, it will be well to avoid unnecessary compression, as this tends to separate the placenta if still attached, and thus to defeat the object for which the cord is left intact.

In many cases of asphyxia neonatorum, to do full justice to both mother and child, and especially when great value is attached to the survival of the latter, the presence of two physicians is desirable. The labours usually associated with asphyxia neonatorum are more or less difficult and involve some danger from post-partum hæmorrhage. In many such cases there is fortunately a colleague present to administer the anæsthetic. I make bold to say, after considerable experience, that when an anæsthetic is necessary, preliminary to instrumental or other artificial delivery, a skilled hand other than that of the operator should always, when possible, administer the anæsthetic. A nurse, however intelligent, is not a responsible person to manage the delivery of the placenta and secure contraction of the uterus; while she is still less able to assist scientifically in the resuscitation of the infant and should never be allowed to anæsthetise the patient or maintain an anæsthesia induced by the accoucheur. The double duties of the physician, in the absence of a trustworthy colleague, are likely to be imperfectly performed towards both patients if their condition is in any way serious. The first duty of the accoucheur is to the mother. His colleague should be responsible for the treatment of the child if born apparently dead.

Having considered the circumstances under which it is permissible to postpone division of the umbilical cord, and those in which its division should take place at once, I have next to consider the means at our disposal for maintaining the double function of that connexion between mother and child—namely, the oxygenation and circulation of the blood in the infant—when the cord has been cut and asphyxia exists. The asphyxiated infant has plenty of blood in its body, sometimes too much, rarely too little. Stillborn infants are said to be heavier by about one-third than children born alive.¹¹ If the possibility of resuscitating the

¹¹ Guy and Ferrier: Forensic Medicine, p. 95.

infant remains, the heart still beats, however feebly; but the source of oxygenation of the blood is cut off completely, and unless oxygen be obtained from another quarter the lingering vitality evinced by cardiac pulsation will also cease.

Marshall Hall, to whom we are indebted for the first real advance in the treatment of these cases (although the elasticity of the chest-wall was utilised before his time), was of opinion that "without due artificial respiration every means of augmenting the circulation must be injurious."¹² He assumed an increased production of carbonic acid under these circumstances. If, however, it be possible to stimulate the circulation while artificial respiration is fully carried out, we cannot suppose that an increased action of that organ which justifies our hope of recovery can render the case more critical. When, as may occur, and as I have myself witnessed in the adult, failure of respiration follows cardiac failure or syncope, artificial respiration may maintain some movement in the heart of a passive character until the accumulation of carbonic acid in the blood, not oxygen, provokes renewed so-called voluntary respiration. Whether the stillstand of the heart in these cases is absolute, or whether some cardiac action continues, cannot be positively stated, for the ventricular systole alone is audible on auscultation and perceptible at the wrist. That ventricular stillstand may be so prolonged as, in the absence of artificial respiration, to point with great probability to a fatal issue is certain. So, also, in the fœtus, artificial respiration, the ultimate object of which is oxygenation of the blood, may to a certain extent influence the cardiac capacity, as all the contents of the chest widen on the creation of a thoracic vacuum. In this case, however, from the persistence of the fœtal channels, the production of cardiac diastole on widening the chest, and its diminution on lessening it, act with less advantage as an aspirator on the pulmonary circulation towards the left ventricle than in the case of the adult and perfect heart. While we may, therefore, assume some change in the chambers of the heart under artificial respiration, we cannot thus quicken its action; such a quickening, however, were it possible, should act both as an aspirator and propeller of the pulmonary and systemic circulation. What thoracic manipulation is to the lungs—an artificial main-

¹² *Asphyxia, its Nature and Remedy*, p. 25.

tenance of the respiratory movements—the introduction of a cardiac accelerator into the blood by hypodermic injection is to the movements of the heart.

The cause of retarded heart's action in the newly born asphyxiated child is probably threefold—viz., lessened sensibility of the cardiac centre, inhibition by way of the pneumogastric nerve, and direct enfeeblement of the cardiac muscle from the circulation of deoxidised blood; the injection, therefore, of such a substance as ether hypodermically is calculated to aggravate rather than remove the central anæsthesia present. That this should be so is not surprising when one bears in mind the effect which an anæsthetic administered to the mother has upon the infant, and likewise the fact that in the analogous case of cyanosis from cardiac malformation alcohol has been found to be badly borne.¹³ On the other hand, the employment of belladonna or atropine is calculated to accelerate the inhibited heart without increasing the insensibility of the patient. In a paper published in *THE LANCET* last autumn¹⁴ “On the Heart as a Guide to Treatment in Infantile Convulsions” I related a remarkable instance of the accelerating influence of belladonna upon the circulation of an infant nineteen days old, in whom both respiration and circulation were all but extinguished; I am, therefore, inclined to believe that the use of belladonna as an adjunct to the employment of artificial respiration may prove of distinct benefit and to be an advance in the treatment of these cases. Lauder Branton,¹⁵ referring to the investigations of Kronecker and Schapiro, states that “when the temperature is low (7° to 8° C.) the ventricular contractions are enlarged by atropine, but diminished by it when the temperature rises over 15° C.” The low temperature, therefore, which characterises any considerable degree of asphyxia neonatorum ought to be favourable to the beneficial action of atropine on the heart.

It has been contended by some, Marshall Hall among others,¹⁶ that to quicken the circulation while pulmonary respiration is impaired is but to promote engorgement of the lungs. In the adult it is possible that this objection may have some force; but, fortunately, in the case of the newly

¹³ Walshe, op. cit., p. 435.

¹⁴ *THE LANCET*, Nov. 4th, 1893.

¹⁵ *Pharmacology, Therapeutics, and Materia Medica*, p. 905.

¹⁶ Op. cit.

born and apparently dead infant it is not valid, for the foetal channels remain open, the pulmonary circulation is limited, and the heart is for a time capable of stimulation by the circulation through it of venous blood. Nor is this merely a theoretical vindication of the procedure I have suggested, for in the interesting and memorable researches of Mr. Erichsen on Asphyxia¹⁷ he repeatedly demonstrated beyond cavil, in the case of young puppies (four days old) in which he found both the ductus arteriosus and the foramen ovale still pervious, that "the quantity of blood that passes through the lungs, and consequently becomes arterial, is (while these channels remain open) but very small." That this should be so is not surprising when one considers that even in the mature embryo the pulmonic circulation must be almost *nil*. William Harvey¹⁸ went so far as to believe that the condition of embryos possessing lungs unused was much the same as that of animals without these organs; but even when the heart is perfect such an acceleration of its action is not likely to congest the lungs seriously, provided artificial respiration be at the same time skilfully employed.

Artificial respiration.—It has been seen in the earlier portion of this article that premature efforts of the foetus to breathe result in the aspiration into the respiratory passages of fluids and foreign substances from the maternal passages. The removal of these as far as possible is a necessary preliminary to ventilation of the lungs. With this object various india-rubber and tubular instruments have been suggested, but they are of questionable utility, and the object they have in view may be better, more expeditiously, and more safely accomplished otherwise—namely, by Schultze's method of artificial respiration, to be described presently. Since the days of Marshall Hall various other methods of artificial respiration have been described and, following the patronymic nomenclature adopted in his case (and first conferred, there is reason to believe, by THE LANCET), have been called by the names of their proposers. Although one cannot altogether admit the "facts insisted upon by Waters in his thoughtful book on "Diseases of the Chest," nor, in consequence, admit the correctness of the argument based upon these when he treats of apnoea in stillborn children, those who have had any prae-

¹⁷ Edinburgh Medical and Surgical Journal, vol. lxxiii.

¹⁸ Op. cit., p. 41.

tical experience of the treatment of asphyxia neonatorum must occasionally have observed that the ultimate respiratory efforts of the child, when these occur, do not always seem to bear a direct relation to the respiratory movements artificially induced. This does not, of course, prove that such efforts have been without influence in establishing respiration and restoring circulation, but give some countenance to the belief expressed by Waters that the respiratory act is in these cases the result of the action of reflex stimuli. It may be that in cases of perfect apnoea, which it has been seen are very rare, his facts and reasoning alike may have some force, but since fluids may be driven out of the lungs there is no *a priori* impossibility of air being driven into them. Expansion of the chest wall by "muscular effort," by which Waters means voluntary muscular effort, is, he believes, the only way to get air into the infant's lungs. It will be seen presently, however, when I refer to Champneys' able paper on the subject in the Transactions of the Royal Medical and Chirurgical Society, that air can under appropriate manipulation be introduced in considerable quantity into such lungs by simulated muscular effort. When Waters wrote, Marshall Hall's method was that chiefly practised, and it is true that in the asphyxiated infant, and by that method, very little air can be introduced into the chest. Champneys¹⁹ classifies the various methods of artificial respiration and gives the *rationale* of their action. By a series of experiments on the dead foetus he also determined approximately the comparative inspiratory and respiratory power of each. As a general result he found the "Silvester group of manipulations" to produce most pulmonary ventilation—that is, the highest degree of inspiration—while that of Schnltze, in its second, or expiratory movement, appeared to be more powerful than any of the others. I may add here, however, that Schultze states²⁰ that during the position of inspiration in his method air may be heard to rush through the glottis with a sound indicating a considerable force of air current. Schnltze's method has an appearance of violence which does not recommend it to those accustomed to gentler methods, but I think its violence is apparent rather than real, and

¹⁹ Transactions of the Royal Medical and Chirurgical Society, [vol. lxiv, p. 42.

²⁰ Loc. cit.,

depends, as do all other methods, very much upon the tact and dexterity of the operator. As to empty the lungs of fluids is our first duty, I shall describe this method now.

Seizing the shoulders of the child as it lies upon its back, so that the thumb of each hand rests upon the anterior aspect of the thorax, while the index finger is hooked into the armpit from behind, and the other fingers are upon the dorsal aspect of the infant's chest, the operator allows the child to hang for a few moments. Then, standing with his legs slightly apart, by an even swinging movement he raises the child with as little compression of the chest as is compatible with a safe grasp of its body, until it reaches a certain point above the horizontal plane. At this point the body gently curls over, bending at the loins, so that the weight of the lower part of the body and the contents of the abdomen press upon the diaphragmatic floor of the thorax and produce the effects of a forcible expiration. It is at this point that aspirated fluids flow freely from the respiratory openings.²¹ This manœuvre may be repeated "after a pause of a few seconds" with gentleness and grace, until as much fluid as possible is expelled. According to Schultze, it is usually during the production of artificial expiration that the first attempt at spontaneous respiration is made. When this is observed, the child should be lowered at once in order to utilise, as far as possible, this artificial inspiratory movement—that during which air may sometimes be heard to whistle through the glottis. Contrary to the advice of the Marshall Hall period, the child may now be placed in a warm bath, in order that the spontaneous respiratory movements may not be interfered with by artificial manipulations. Here, as in many other circumstances, Talleyrand's advice finds application: "*Surtout point trop de zèle.*" There are many who use Schultze's method throughout. Inasmuch, however, as greater inspiratory power is resident in Silvester's method and its modifications, the child may, after being freed from aspirated fluids, be laid on its back, so that there is as little stretching of the anterior surface of the body as possible—a tension which, as Champneys points out, prevents the full development of the thoracic vacuum—and that group of manipulations carried out. An assistant may now fix the legs, while the arms are seized at any convenient

²¹ Schultze, loc. cit., p. 40.

point in order to exert efficient upward traction on the shoulder girdle and ribs. I prefer seizing the arms a little above the elbows. Traction may then be steadily made upwards and slightly forwards, as if withdrawing the piston of a syringe, until the utmost stretching of the thorax compatible with gentleness has been reached. The arms may then be brought to the sides again, and the manœuvre repeated. Before such repetition the hands of the operator may make gentle pressure on the lower part of the thorax in order to simulate expiration. Inasmuch, however, as the diaphragm is already in the position of expiration, or nearly so, this is not so important as a repetition of the movement inducing inspiration. In the absence of spontaneous attempts at respiration these acts should not follow one another too hurriedly, but must be sufficiently slowly and deliberately performed to produce the greatest vacuum possible; but, as the normal rate of infantile respiration is greater than in larger subjects, they must be repeated more frequently than in the suspended animation of the latter.

When resuscitation is possible the methods I have described, capable as they are respectively of producing the highest degree of inspiration and expiration, will suffice. Attempts to inflate the lungs directly by blowing into the mouth of the child, or by other direct means of inflation, are inferior to the methods mentioned, not devoid of danger to the parts insufflated, and totally erroneous in theory. Methods of direct inflation, in short, imply the ignoring or ignorance of the cardiac factor in suspended animation. This our second object, of favouring the development and action of the chambers of the heart and the current of blood through the intra-thoracic vessels, far from being attained by direct insufflation of the lungs, is more likely to be thwarted. The inflated lungs, in order to expand and raise the walls of the chest, even if they be not injured by the degree of insufflation calculated to produce this effect, must use as a fulcrum the heart, great vessels, and contents of the mediastina generally. In other words, they must exert a pressure upon those parts calculated to arrest the circulation before they could be expected to expand the thorax, as in the act of voluntary or simulated inspiration by muscular effort. More progress will therefore be made by perseverance with the method of artificial muscular respiration selected, and of the *rationale* of which the operator

has an intelligent conception, than by irresolute and hurried endeavours of various kinds, some of which are based upon erroneous ideas of the work to be done.

For what length of time should we persevere in our efforts to restore the child? As Marshall Hall²² remarks—and in doing so he quotes so ancient an authority in support of his observation as William Harvey—the newly born and apparently dead foetus can survive much longer without respiration than can a child or other subject which has breathed fully. It has also been observed that a child “from his mother’s womb untimely ripped” by Cæsarean section can be resuscitated after a longer interval than the child extruded in natural labour.²³ In view, therefore, of these facts, attempts to restore the child by artificial respiration must be continued for a considerable length of time—Marshall Hall says for hours. Speaking from my own experience, however, there is little utility in prolonging our efforts much beyond the time when the heart has definitely ceased to beat, as determined by auscultation. But there is this fallacy in auscultation, that it is only the ventricular pulsation which can be detected by the stethoscope, and, in view of a possible persistence of auricular action, it may be well to persevere for a time—how long one cannot say in any particular case—even after the heart has ceased to be heard beating. The motto adopted by the Humane Society, and with which Marshall Hall concludes the essay to which I have referred, “*Lateat scintilla forsitan*,” is an encouragement to persevere until there is every probability of the spark of life having been finally extinguished. As regards the influence of other stimuli than that of the external temperature on the body of the infant, a variety of opinion is permissible and exists. Champneys²⁴ says such are of no use in the pale stage of asphyxia neonatorum. That they are not of great use may be admitted; that they need never be of a violent description is certain; but that they are of no use at all in such cases is more doubtful. While the operator is concerned with the measure-in-chief there is no objection to an assistant using gentle friction with some mild stimulant, such as brandy or a weak solution of ammonia, and the application of external warmth alternating in some instances with cold by means of a sponge.

²² Op. cit.

²³ Barnes, op. cit.

²⁴ Loc. cit.

The limbs may, as Marshall Hall suggests, be gently rubbed in an upward direction to promote the return of venous blood. If such measures do not directly provoke spontaneous respiration they cannot prevent it, and may therefore be employed. The less profound the asphyxia the more likely are such measures to succeed ; nay, in milder cases they may be even more potent than artificial respiration. It is a common occurrence to observe a direct provocation of the respiratory reflex in such cases. In this connexion it is necessary to mention the method of resuscitation by rhythmical tractions of the tongue, an account of which has recently been published by Laborde.²⁵ The writer regards it as operating upon the respiratory reflex by way of the superior laryngeal, glosso-pharyngeal, and lingual nerves—the nerves stimulated by the process of traction. Any effect of the process upon the circulatory system he regards as secondary to its influence upon the mechanism of respiration. Following the line of thought and observation, however, which has been pursued in this article, a possibly direct influence of this process upon the heart by way of the pharyngeal plexus cannot be excluded. “Kronecker,”²⁶ says Lauder Brunton, “has discovered that the act of swallowing seems to remove entirely the inhibitory action of the vagus upon the heart for the time being, so that the pulse becomes exceedingly rapid. The extent to which this occurs will hardly be credited by anyone who has not tried the experiment.” As Laborde²⁷ shows, the heart of asphyxia is an inhibited heart—it dies in diastole. A proceeding, therefore, which is calculated to modify vagus action may also be operative in the process of resuscitation. The sighing respiration accompanying a heart depressed from disease or emotion is due to a pneumogastric reflex having its maximum stimulation in the vascular system or brain, as the case may be. The lungs are thus summoned to aid the heart by the heart. In these cases, as I have shown, the injection of belladonna may render signal service. It has, moreover, this advantage, that an agent in the blood is allowed to deal, as it very effectually can, with the cardiac inhibition ; while the physician is left with two hands to employ that form of

²⁵ *Les Tractions Rythmées de la Langue*, Paris, 1894.

²⁶ *Disorders of Digestion*, 1886, p. 11.

²⁷ *Op. cit.*, p. 159-161.

artificial respiration or other manipulation which the case indicates. It is a great recommendation of Laborde's process that it is very simple and always capable of application. Remembering that children, cast aside as dead, have frequently recovered, it is our duty systematically and methodically to persevere in the conjoint use of all means likely to promote recovery until we are convinced that further effort is futile.

